Segments Organization by Cluster Analysis

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Abstract

An efficient Segments Organization plays an important role in the design of high performance data base.

This paper describes a new method to organize a lot of data-items into proper segments which diminishes data access overhead remarkably. In the process of organization, Cluster Analysis which is widely used in the field of multivariate analysis, is employed to cluster data-items.

Simulation results showed this method reduced data access overhead by 35 ~ 45 %.

1. Introduction:

It is well known that organization of segments influences greatly on the data base performance. A segment can be defined as a logical unit of store and reference no matter what kind of storage devices are used. From the viewpoint of access overhead, it is desirable that data items referred to together by an application program should exist in the same segment. On the contrary, as the data base is used by many application programs, to integrate a large amount of data items into one segment increases the transfer overhead prohibitively.

This paper describes a new technique to organize effective segments in the design of data base. Cluster Analysis is employed to classify a lot of data items into proper segments. Experimental results show segments organized by this technique can achieve a very high performance.

There have been reports[3][4] about the reduction of I/O overhead; however, the technique presented here depends less on physical characteristics of storage devices and, therefore, can be applied widely in the design of data base.

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2. Segments Organization of Data Base:

First, we define some terminology used in this paper. An item is a minimum logical data unit. A segment is a minimum logical unit of store and reference, which is composed of several items. An application means a process which refers to various items.

We denote the set of application by $G = \{ g_1, g_2, \cdots, g_p, \cdots g_r \}$.
The whole set of items $I = \{ \alpha_1, \alpha_2, \cdots\cdots, \alpha_n \}$ is given as follows, where I_{g_p} is the set of items referred to by application g_p.

$$I = I_{g_1} \cup I_{g_2} \cup \cdots\cdots \cup I_{g_p} \cup \cdots \cup I_{g_r} \quad (1)$$

Relations between applications and items can be represented by reference matrix $R = \{ r_{pq} \}$. r_{pq} equal to 0 if g_p refers to α_q and 0 otherwise.

By classifying I, we organize m segments S_k ($k = 1, 2, \ldots m$), which forms the set of segments $S = \{ S_1, S_2, \cdots\cdots, S_m \}$. It is assumed that each item belongs to only one segment but never to several different ones.

Next we define an evaluation function by eq.(2), which corresponds to the effectiveness of S. I_{S_k} represents the set of items composing S_k.

$$\left.\begin{aligned} \varphi &\triangleq \sum_{p=1}^{r} \left[w_p \sum_{k=1}^{m} (\triangle T(p,k) + \triangle A(p,k)) \cdot \delta_{kp} \right] \\ \delta_{kp} &= \begin{cases} 1 : I_{s_k} \cap I_{g_p} \neq \phi \\ 0 : I_{s_k} \cap I_{g_p} = \phi \end{cases} \end{aligned}\right\} \quad (2)$$

Here, w_p is a weighting factor which indicates the processing frequency of g_p. $\triangle A(p,k)$ means the overhead to have access to S_k by g_p. And $\triangle T(p,k)$ corresponds to the overhead to transfer S_k between storing area and processing area by g_p. Consequently, $(\triangle T(p,k) + \triangle A(p,k))$ corresponds to the overhead of reference to S_k by g_p.

After all, our objective to be achieved is the organization of the segment set S which minimizes φ defined by eq.(2).

3. Optimal Segments Organization by Cluster Analysis:

We employed hierarchical Cluster Analysis [1][2] to realize S which gives as small φ as possible. The distance (inverse of connectivity) between items and clusters must be predefined for the clustering. d_{ij}, indicating the distance between item α_i and α_j, is given as follows:

$$
\left.\begin{aligned}
d_{ij} = d_{ji} = C \Big/ \sum_{p=1}^{r} w_p \cdot \delta_{pij} \quad (i, j = 1, 2, \cdots, n) \\
\delta_{pij} = \begin{cases} 1 : \alpha_i, \alpha_j \in I_{g_p} \\ 0 : \alpha_i \notin I_{g_p} \text{ or } \alpha_j \notin I_{g_p} \end{cases}
\end{aligned}\right\} \quad \text{------------ (3)}
$$

C : constant value

Where w_p is average processing frequency multiplied by average number of cases per one processing. The distance between cluster C_x and C_y is defined to be

$\min_{\alpha_i \in C_x, \alpha_j \in C_y} d_{ij}$ which is called Nearest Neighbor.

On the basis of the above definitions, Single Linkage Method and Hierarchical Mode Method are employed as a clustering algorithm. In the clustering process, the most strongly connected two clusters are clustered one after another in principle.

The result of cluster analysis is obtained as a dendrogram. In a dendrogram, items are listed on the abscissa, and the length in the ordinate is equivalent to the strength of relation between items. By cutting the dendrogram off at a proper point on the ordinate, we can obtain clusters as groups of items interconnected with each other.

We organize segments from the items included in each cluster. The reason why we can attain small $\mathcal{T}$ is obvious; because those items which are often referred to together should be classified into the same cluster.

4. Experimental Results

4.1 Example System:

An Actual batch processing application system is treated as an example. The system is composed of

Table. 1 Examples of Segments organized by Cluster Analysis.

Organization \ Segment	number of items belong to s_1	number of items belong to s_2
S_A	14	15
S_B	21	8

34 applications $G = \{g_1, g_2, \cdots, g_{34}\}$ and 29 items $I = \{\alpha_1, \alpha_2, \cdots, \alpha_{29}\}$. An item length ℓ_q (q=1, 2, ..., 29) is from 1 to 30 bytes, and total length $\sum_{q=1}^{29} \ell_q$ equal

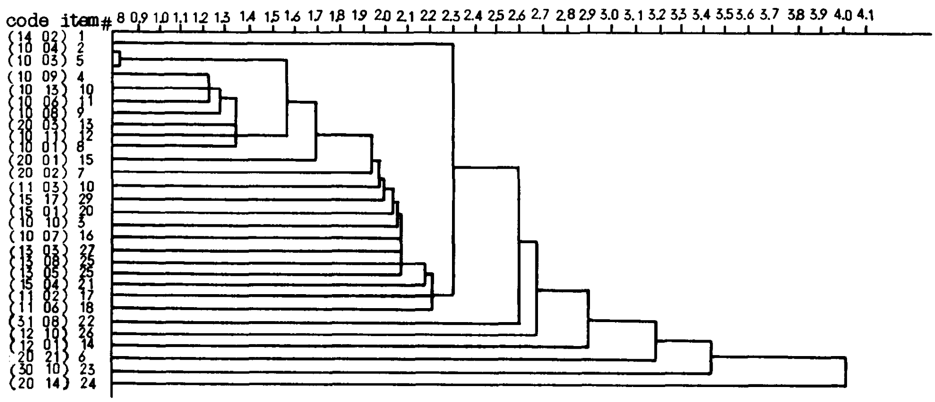

Fig.1 Dendrogram Example: the result of clustering items by Single Linkage Method.

to 178 bytes; 15 items are used as a key item of reference, and the total amount of data is about 1,000,000.

The dendrogram resulting from Cluster Analysis is shown in Fig. 1. We organized two kinds of segment sets S_A and S_B (Table 1), by cutting off the dendrogram.

Large capacity magnetic disks are chosen as storage devices. Indexed Sequential Organization is employed with the primary key which is most often used as a key item by G. Secondary indexes are also made for those applications using other keys.

4.2 Investigation by Evaluating Function Ψ and Simulation Verification:

We calculated the evaluation value for S_A and S_B given by eq.(2). In eq.(2),$\triangle T(p, k)$ is average transfer time between disk track and main memory, and $\triangle A(p, k)$ is average access time using ISAM(Indexed Sequential

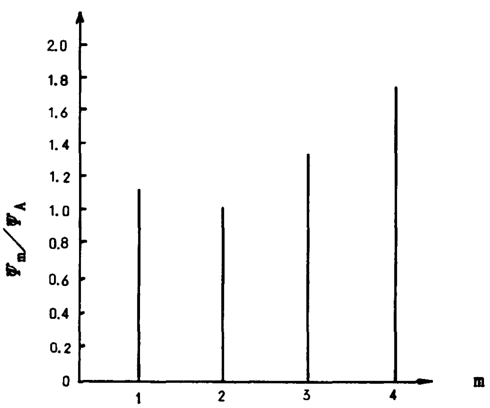

Fig. 2 Variation of Performance with number of segments m.

Access Method) and, if necessary, Secondary Index.

Table. 2 Performance Comparison estimated by Evaluation Value Ψ , in the case m = 2.

Ψ_0/Ψ_A	Ψ_0'/Ψ_A	Ψ_B/Ψ_A
1.86	1.61	1.06

The result is shown in Table 2, where Ψ_A and Ψ_B correspond to S_A and S_B respectively. Ψ_0 and Ψ_0' correspond to S_0 and S_0' which are both organized by dividing all items into two groups at random. It is shown that the employment of cluster analysis decreased the value Ψ by 35 ~ 45 %. Ψ_A is about 6 % smaller than Ψ_B, so that S_A is more effective than S_B in our experiment.

Table. 3 Performance Comparison estimated by simulated I/O total time, in the case m = 2..

T_0/T_A	T_0'/T_A	T_B/T_A
1.71	1.55	1.02

In addition, S_A(m=2) was compared with the segment set of m=1 and m≥3. In Fig. 2,m=1 represents the case in which all items are integrated into one unique segment, and m≥3 corresponds to segments made by multi-division of dendrogram. In our experiment, m=2 gives minimum value because transfer overhead T increases at m=1, and access overhead $\triangle A$ increases at m≥3.

As discussed above, S_A is considered to be the segment set which gives very small Ψ , not to say an optimal one.

Table 3 shows simulation results executed on the same application system. In Table 3, T_A, T_B, T_0 and T_0' indicate simulated I/O total times referring to S_A, S_B, S_0 and S_0' , respectively. Comparison between Table 2 and Table 3 verifies the propriety of the evaluation function Ψ and the effectiveness of segments organization by cluster analysis.

5. Conclusion:

A Cluster Analysis technique for organizing segments of data bases is presented. It was found that this technique has reduced by 35 ~ 45 % the reference overhead compared with those organized at random.

6. References:

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